Effects of elevated CO_2 on net photosynthetic rate of trees in Changbai Mountain[1]

Wang Chenrui (王琛瑞) Han Shijie (韩士杰)

Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110015, P. R. China

Abstract Net photosynthetic rates (NPRs) of four species seedlings, *Pinus koraiensis*, *Pinus sylvestriformis*, *Fraxinus mandshurica* and *Phellodendron amurense*, were measured at different CO_2 concentrations and time respectively in Changbai Mountain during the growing season in 1999. The seedlings were cultivated in open-top chambers (OTCs), located outdoors and exposed to natural sunlight. The experimental objects were divided into four groups by tree species. CO_2 concentrations in chambers were kept at 500 $\mu L \cdot L^{-1}$ and 700 $\mu L \cdot L^{-1}$ and contrast chamber and contrast field were set. The results showed that the effects of elevated CO_2 on NPR of the trees strongly depended on tree species and time. NPRs of *Pinus koreainsis* and *Pinus sylvestriformis* seedlings increased with the rising of CO_2 concentration, while that of *Phellodendron amurense* and *Fraxinus mandshurica* increased at some time and decreased at another time.

Key words: Elevated CO_2, Net photosynthetic rate, Trees, Changbai Mountain

Introduction

Atmospheric concentration of CO_2 is rising dramatically and a doubling of the present concentration would occur in mid next century, due to burn of fossil fuel and destroy of forest (Gates 1983; Tausz *et al.* 1996). Elevated atmospheric CO_2 will change its gradient distribution in forest ecoboundary, and will produce a great effect on trees and the whole forest ecosystem. At present, studies on effects of elevated CO_2 on plants have been a popular topic, especially on crops rice (Bater *et al.* 1990). Havelka *et al.* (1984) has gained many achievements on soybean. However, in this aspect as to the research of trees and forest is unsatisfactory, the results from their experiments are different, and even contrary sometimes, as a result of varied experimental sites, objects, methods, and the apparatus and equipment.

Forests of Changbai Mountain play an important role in the global ecosystems. *Pinus koraiensis*, *Pinus sylvestriformis*, *Phellodendron amurense* and *Fraxinus mandshurica* are main tree species in this area. It is significant to study the results of the global change and the effects of elevated CO_2 on trees' main physiological process--photosynthesis at different growth stage of various trees. The most widely used approach for long term CO_2 enrichment is the classic open top chamber (OTC), originally designed for air pollution studies (Olszck *et al.* 1980). In this paper we studied the effects of elevated CO_2 on net photosynthetic rate (NPR) of seedlings of four representative tree species by CI-301 Gas Analyzer in OTCs at different CO_2 concentrations.

Experimental field

The experimental field was located in the Opened Research Station of Changbai Mountain Forest Ecosystems (128°06' E, 42°24' N), at altitude of 738.1 m, in Erdao Town of Antu County, Jilin Province. It lies in the broad-leaved Korean pine vegetation zone. Soil is mountain dark brown forest soil. Climate type belongs to continental monsoon influenced temperate zone mountain climate. Annual mean air temperature is 5.0℃. Total annual precipitation is 719.3 mm. Annual general sunlight time is 2015.3 h. Frost-free period lasts 116 d.

Materials and methods

CO_2 concentration and NPRs were determined with CI-301 CO_2 Gas Analyzer. We used the open system (Fig. 1), the velocity of air flow is 1.5 $L \cdot min^{-1}$, equipped with narrow leaf chamber (6.5 cm × 10 cm) that was made of colorless plexiglas, two small electric fans were set in order to lower boundary layer separation.

Leaf area was measured with leaf area apparatus. The calculating formula of NPR of open system is as follows:

$$P_n = -w(C_o - C_i) = -\frac{2005.39vp(C_o - C_i)}{AT_\alpha}$$

Where P_n is NPR ($\mu mol \cdot m^{-2} \cdot s^{-1}$); C_O (C_i) is CO_2 output (input) concentration ($\mu L \cdot L^{-1}$ or $\mu mol \cdot mol^{-1}$); W is the

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mass velocity of flow ($mol.m^{-2}.s^{-1}$) per units leaf area in the open system; P is atmospheric press (bar); V is volume velocity of flow (leaf/min); T_a is atmospheric temperature (K); A is leaf area (cm^2)

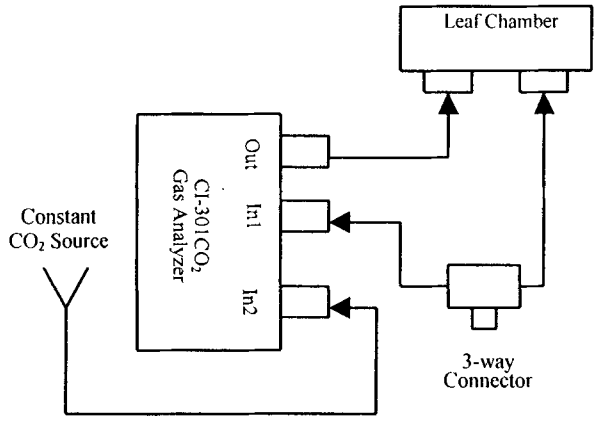

Fig. 1. The sketch map of open system pipelines (Ceulemans 1994)

The OTCs are made of transparent plexiglas with metal frames, with a size: 1.3 m (length)×0.9 m (width)×1.2 m (height). Dry-wet hygrometers were set in chambers to control the temperature and humidity. And for controlling the sunlight intensity the OTCs were covered over with sunshades.

The experimental objects were divided into four groups according to tree species, three OTCs and one contrast field per group set on the same field. The CO_2 concentration was controlled at 700 $\mu L.L^{-1}$ in one OTC, and at the level of 500 $\mu L.L^{-1}$ in another, by pumping CO_2 gas The contrast chamber and contrast field were not added CO_2.

The experimental trees (*Pinus koraiensis*, *Pinus sylvestriformis*, *Fraxinus mandshurica* and *Phellodendron amurense*) are 1-year old seedlings.

NPRs of tree species were measured at seven time points (6:00, 8:00, 10:00, 12:00, 14:00, 16:00 and 18:00) during a selected sunny day. The mean values were utilized in analysis.

Results and analysis

From Fig. 2 and Fig. 3, we can see that there is no significant difference in NPRs between contrast field and contrast chamber. Seedlings of two conifers placed in chamber with CO_2 concentration of 700 $\mu L.L^{-1}$ have the highest NPRs at every time point. The NPRs of the seedlings treated with CO_2 concentration of 500 $\mu L.L^{-1}$ were lower than that at 700 $\mu L.L^{-1}$, but much higher than those of contrast field and in contrast chamber. Consequently we believe that elevated CO_2 can improve the NPRs of *Pinus koraiensis* and *Pinus sylvestriformis*. The high NPRs value of *Pinus koraiensis* occurred at afternoon, while that of *Pinus sylvestriformis* occurred at 10:00 a.m., which might be the result of different responses to temperature.

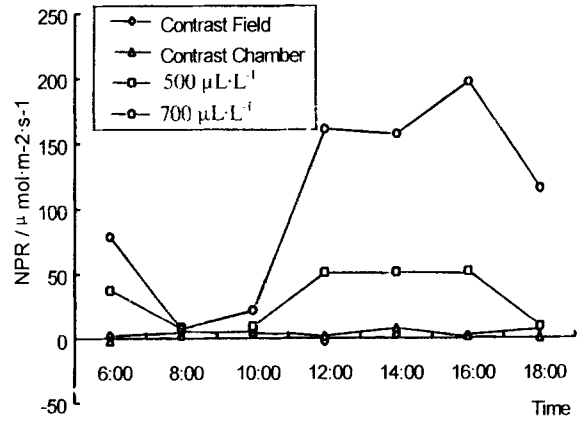

Fig. 2. Day dynamics of photosynthetic efficiency of *Pinus koraiensis*

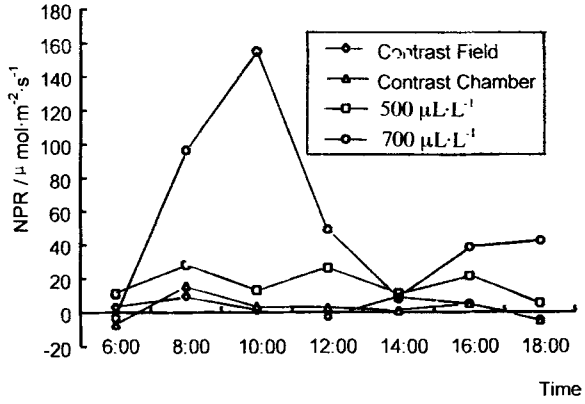

Fig. 3. Day dynamics of photosynthetic efficiency of *Pinus syvestriformis*

As compared to coniferous seedlings, the effects of elevated CO_2 on two broad-leaved tree species, *Phellodendron amurense* and *Fraxinus mandshurica*, are more complicated. It is not evident that NPR increases with elevating of CO_2 concentrations (Fig. 4 and Fig. 5). The NPR of *Phellodendron amurense* seedlings was higher at 500 $\mu L.L^{-1}$ than at 700 $\mu L.L^{-1}$ at time point 6:00, 16:00 and 18:00. This indicates that CO_2 concentration of 500 $\mu L.L^{-1}$ is suitable for photosynthesis of this species under lower sunlight. The highest NPR points for the seedlings both in chambers and contrast field all occurred at 10:00 a.m.. Elevated CO^2 made seedlings keep photosynthesis at 18:00 p.m. while at this time the seedlings of the contrast field and the contrast chamber had a negative value of NPRs. In addition, the effects of elevated CO_2 on NPRs of *Phellodendron amurense*

changed with time (Fig. 4), for example, the NPRs of seedlings in the contrast chamber are higher than in the chamber with 500 $\mu L \cdot L^{-1}$ CO_2 concentration.

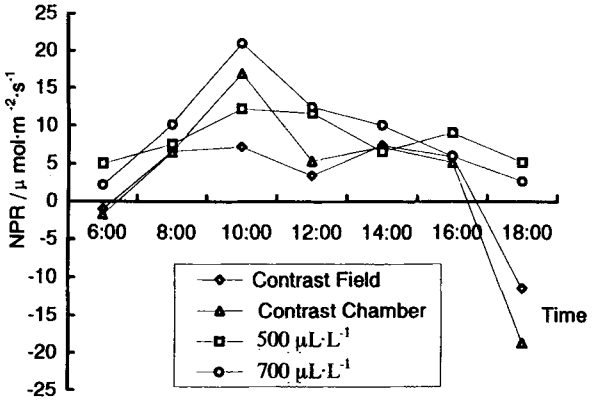

Fig. 4. Day dynamics of photosynthetic efficiency of *Phellodendron amurense*

Effect of elevated CO_2 on NPR of *Fraxinus mandshurica* is also complicated. The highest NPR values occur at different time (Fig. 5); the NPR of seedlings at CO_2 concentration of 700 $\mu L \cdot L^{-1}$ is higher at 10:00, 12:00, 14: 00 hours. Seedlings in contrast chamber and contrast field had negative NPR value at 12:00 hour, while NPRs of chambers with elevated CO_2 were still positive at this time though the values were lower. This indicates that elevated CO_2 can promote photosynthesis in condition of high temperature and sunlight. NPRs of seedlings in the chambers with high CO_2 concentration were lower than that in contrast chamber and contrast field at 6:00 and 8:00 a.m., which indicates that elevated CO_2 restrain the photosynthesis of seedlings at the two-time points.

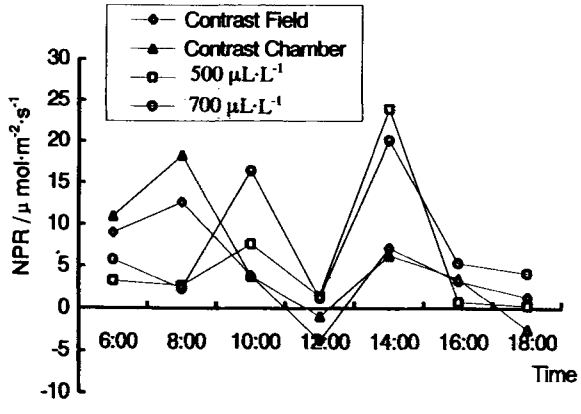

Fig. 5. Day dynamics of photosynthetic efficiency of *Fraxlmus mundshurica*

From above analysis, it is concluded that the effects of elevated CO_2 on NPR strongly depends on tree species and time. NPRs of *Pinus koraiensis* and *Pinus sylvestriformis* increase with the elevation of CO_2 concentration at any time, but that on two broad-leaves tree species, *Phellodendron amurense* and *Fraxinus mandshurica*, it changes with time.

Discussion

OTC that provides growth environment similar to nature does not limit root growth and CO_2 concentration can be controlled with change of temperature, but it may change environmental temperature and sunlight. Although the environmental parameters in these OTCs differ only slightly from outside, some effects on temperature, relative humidity and wind speed cannot be excluded. Therefore, an exact knowledge of the environment within the OTC and a comparison with the outside conditions remains necessary. Using OTC cost much because of large CO_2 consumption and requiring large storage containers (Ceulemans *et. al.* 1994). Meanwhile, we believe that further study is necessary on effects of elevated CO_2 on various trees at their different growth stage in the future.

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References

Bater, J.T, Anllen, L.H, Boote, K.J. 1990. Growth and yield responses of rice to carbon dioxide concentration. Journal Agriculture Sciences, **115**: 313-320

Ceulemans, R. and Mousseau, M. 1994. Tansley Review No.71 Effects of elevated atmospheric CO_2 on woody plants. New Phytol., **127**: 425-446

Gates, D.M.I. 1983. CO_2 and plants, West view presses. Boulder, Colorado, 7-20.

Havelka, U.D.R., Ackerson, C., Boyle, M.G, *et al.* 1984. CO_2-Enrichment effects on soybean physiology, Crop Science. **24**( ): 1146-1150.

Olszyck, D.M., Tibbits, T.M., Hertsberg, W.M., 1980. Environment in open-top field chambers utilized for air pollution studies. Journal of Environmental Quality **9**(): 610-615

Tausz, M., Luit, J. De Kok, Stulen, I., and Grill, D. 1996. Physiological responses of Norway Spruce Trees to Elevated CO_2 and SO_2, J. Plant Physiol., **148**: 362-367

Tegart, W.J McG., Sheldon, G.W. and Grifiths, D.C. editors. 1990. Climate change, the IPCC impacts assessment. Australian Government Publishing Service, **2**(1/2): 21